BME 8730

Fall 2019

Transducer Model – Part 2.

Implement the two variations of 1.4.18 (Kino) for each of transmitter and receiver.

Use the following material properties – which apply to 3203HD which is a commonly used high sensitivity (low power) piezoceramic.

33 = 1200 \* 8.8543e-12

rho = 7820

cE11 = 1.3745e11

cE33 = 1.2574e11

cE12 = 0.8790e11

cE13 = 0.9230e11

e31 = -9.440

e33 = 22.495

Assume that the element is 12 mm long (elevation), 0.3 mm wide (azimuth) and 0.8 mm thick. This corresponds approximately to a 2 MHz cardiac transducer element.

Assume that the element operates into a water load (Z=1.5 MRayl) and that the backing is 4 MRayl. (A real element might include one or more matching layers. The backing impedance is a tradeoff – lighter materials giving a higher sensitivity but lower bandwidth.)

Use an impulse excitation (all 1’s in frequency domain).

Plot the pressure output into water as both a spectrum (FD) and as a time domain (TD) pulse.

When calculating the time domain pulse, you will get a cleaner response if you cut off components above twice the fundamental resonant peak. Plot the result with and without elimination of the harmonics. (Although the harmonics may be eliminated, you may still want to zero pad the spectrum to a higher frequency – like 10 MHz – to get a finely sampled time domain pulse)

Exercises (10pts each):

1. Implement a square pulse excitation. The cheapest implementation is using a half cycle square wave with center frequency matched to that of the transducer – i.e. 2 MHz. i.e. create a mono-polar pulse with a duration equal to one half of the period of a 2 MHz signal.

I suggest you use your frequency domain code and perform an IFFT to obtain the impulse response in the time domain. Verify that you can take an FFT of your IFFT and get back to the original response coming out of the transducer. Now, replace the time domain pulse with this one described above and FFT it so as to get the right sampling and array length as is used in your transducer model. Since you have the transducer impulse response (frequency domain), you can obtain the response of the square wave pulse by multiplying the FD version of the square wave with the transducer impulse response (FD) and then taking IFFT to obtain the final pulse shape. Plot of the FD and TD of the output pulse resulting from the single cycle excitation.

2. Repeat the above using a two cycle excitation – same center frequency. Plot the FD and TD transmit output. Verify that the signal bandwidth is reduced and that the TD pulse amplitude is increased (why?).

3. Calculate the modified elastic stiffness and piezoelectric coefficient for the sliced (thin) array element. You can also include the modified permittivity but the difference is insignificant. Repeat 2. above and measure the increase in signal bandwidth (ideally at -6dB level) and pulse (TD) amplitude.

4. Using modified coefficients from 3, replace 4 MRayl backing with 1 MRayl backing and with 10 MRayl backing. Using a single cycle excitation. Verify that the expected impact on FD (bandwidth) and pulse duration (TD) are obtained. (The heavier backing sinks more energy more quickly because it is closer to an impedance match.) Note the impact on pulse amplitude.

5. Go back to the 4 MRayl condition (modified coefficients). Calculate the impedance of the transducer. Using a series circuit analysis, plot the transmitted impulse response (FD) for both the open circuit case and the 50 ohm source case.

6. As in 5, using 4 MRayl condition and modified coefficients, using a series circuit analysis, calculate the open circuit receiver impulse response (FD) and the response across a 50 ohm load (FD) (i.e. the receiver amplifier input impedance is 50 ohms) taking account of the transducer internal electrical impedance and the transducer open circuit receiver response.

When using a transducer electrical impedance in 5 and 6, keep in mind that you need to use the impedance calculated for that precise transducer configuration – i.e. all the correct transducer parameters and acoustic loading conditions.

Why would it not necessarily make sense to use an open circuit (or open circuit approximation) for a receiver input? (Hint: signal to noise, Johnson (thermal) noise)

When comparing two conditions in terms of their spectral (FD) response, use the same normalization factor for both curves so that you can compare the amplitudes – otherwise they will both normalize to 0 dB and provide an inaccurate comparison. (e.g. normalize by the maximum value of the highest value obtain across each of the two curves you are normalizing)

I suggest you plot -60dB to 0dB on the y-axis for your spectra. There is little practical value in the information less than -60dB or possibly even less than -40 dB.

7. Using the following paper:

“Modeling 1-3 Composite Piezoelectrics : Thickness-Mode Oscillations”

Wallace Arden Smith, and Bertram A. Auld IEEE TRANSACTIONS ON ULTRASONICS, FERROELECTRICS. AND FREQUENCY CONTROL. VOL. 38. NO. I . JANUARY 1991

(Available on collab)

Implement equations 17-25 (you can exclude Eqn 20). Hence, reproduce Figs 3 and 4 for all parameters listed.